

A BUFFER STOCK MODEL FOR STABILIZING PRICE WITH CONSIDERING THE EXPECTATION STAKEHOLDERS IN THE STAPLE-FOOD DISTRIBUTION SYSTEM

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ABSTRACT

The extremely different supplies between the harvest season and the planting season are one of serious problem in the staple-food distribution system. In free-market mechanism, this extreme difference will trigger price-volatility and shortage of staple-food. This situation causes opportunity-losses for the stakeholders (producer, consumer, agent and government) in the staple-food distribution system. The government has got incurred losses because the government cannot achieve food-security for the households. The government has several price stabilization policies; one of them is market intervention policy by using buffer stock schemes to stabilize price and to reduce losses for the stakeholders. The objective of this research is to determine the buffer stock schemes required for market-intervention program. In the previous researches, the buffer stock models have been developed separately based on optimization and econometrics methods. Optimizations methods have been used to determine the level of availability with schemes consist of time and quantity of buffer stock. Econometrics methods have been used to determine the equilibrium price by using the selling-price and the amount of buffer stock. In this research, the integration of optimization model (multi-objectives programming) and econometrics model are used to develop a buffer stock model with the decision variables that consist of quantity, time, and price.

Key Words: Buffer Stock Model, Market-Intervention, Price-Stabilization.

1. INTRODUCTION

Supplies of staple-food in agro-industry, such as sugar, are extremely different between the harvest season and the planting season (Reiner and Trcka, 2004, Susila and Sinaga, 2005). This extreme difference will trigger price-volatility and shortage of staple-food. The volatility and shortage can lead the food-security problems, especially related to the scarcity and price-hikes for households (ISO, 2005, Mardiyanto, *et al*, 2005, Susilo, 2006); and related to

the crisis of economics and social when the food-security problems are not controlled (Smith, 1997, Brennan, 2003). This situation causes opportunity-losses for the stakeholders (producer, consumer, agent/trader, and government) in the staple-food distribution system. The stakeholders will get losses because the producer is forced to sell staple-food at lowest price during the harvest season; the consumer has to deal with the scarcity of staple-food and price hikes during the planting season; the agent is forced to spend a larger procurement cost and they lack goods; and the government cannot achieve food security for the households.

There are some problems that should be considered in this research, related to the real problems of staple-food. The amount of production is lower than the amount of consumption. Consequently, import of staple-food is permitted by the government to anticipate market shortage (Isma'il, 2001, Khudori, 2002, Mardiyanto *et al.*, 2005). The government regulates the import mechanism. However, the procurement time is limited during out of harvest season. The staple-food has high fluctuation in selling price in a year (International Sugar Organization, 2005, Susila and Sinaga, 2005, Susila, 2006). Therefore, market intervention program should be conducted by the government to reduce market risks and to maintain food-security. The government has several price stabilization policies; one of them is market-intervention program by using buffer stock schemes (Athanasioa *et al.*, 2008).

Buffer stock is a part of inventory as a reserve against short-term shortages and/or to dampen excessive fluctuations from supplier (Nur Bahagia, 2006). The buffer stock formulation is identical with safety stock formulation, it is only different in the context of uncertainty to be anticipated (Tersine, 1994). The government should reduce losses for the stakeholders by storing a certain amount of the staple-food in boom periods so that the market-price goes up (price-support program); and releases a certain amount of the stored staple-food in bust periods so that market-prices goes down (price-stabilization program). In order to maintain the expectation of stakeholders, the government can apply the buffer stock schemes to maintain the market-price on certain price-band (William and Wright, 2005). The buffer stock schemes consist of planning, procurement, inventory, and operation program (Nur Bahagia, 2006).

Several authors have addressed to the development of mathematical frameworks to investigate the effects of market-intervention program. They are Nguyen (1980), Newbwry and Stiglitz (1982), Jha and Srinivasan (2001), Brennan (2003), Athanasioa *et al.* (2008) and Sutopo *et al.* (2008) who have dealt with the stabilization problems by using buffer stock. Nguyen (1980) proposed a simple rule for the buffer stock authorities to stabilize both price and earnings in every circumstances, not including when market is instable. Newbwry and Stiglitz (1982), Jha and Srinivasan (2001) and Brennan (2003) have developed the buffer stock supply model considering price balance at price band policy. These models had been developed to assure welfare both producer and consumer by government's intervene, but these models have not considered budget relative with the price-stabilization program yet. However, Jha and Srinivasan (2001) did not consider effectiveness of budgets. Another paper, Athanasioa *et al.* (2008) presented a Cobweb model with rise of supply according to a certain piecewise of linear supply function. Furthermore, Sutopo *et al.* (2008) developed a buffer stock model for stabilizing price of commodity under limited time of supply and continuous consumption.

The previous models cannot dampen excessive fluctuations of supplier side that consist of amount, price and time simultaneously. In previous researches, the buffer stock models had been developed separately based on optimization methods and econometrics methods. Optimization methods have been used to determine the level of availability with buffer stock schemes consisting of time and amount of buffer stocks. Econometrics methods have been used to determine the equilibrium price by using the selling price and the amount of buffer

stocks. We diagnosed a research-question according to the real problems and the mapping of previous researches. The objective of this research is to determine the buffer stock schemes required for market-intervention program by considering the interests of stakeholders. In this research, the integration of optimization method and econometrics method are used to develop a buffer stock model for stabilizing price by considering the stakeholder's expectation.

2. MODELLING FRAMEWORK

In Figure 1, we present the stocks and flows model for stabilizing price through market-intervention program. In this research, we have studied a single commodity produced by the factory and distributed to the consumer through the mediation of agent in free market. The market-prices are determined through 4 periods as follows:

- (i) the early of harvest season (period t_0-t_1),
- (ii) the end of harvest season (period t_1-t_2),
- (iii) the beginning of planting season (period t_2-t_3), and
- (iv) the end of planting season (period t_3-t_4).

The structural aspect consists of three components of supply-chain entities (producer, agent, and consumer) and a regulator (government) where in this case assumed that each entity has only 1 player. The functional aspects consist of the producer-agent-customer relationship based on the free market mechanisms; and the producer-government-customer relationship based on the intervention of market mechanism.

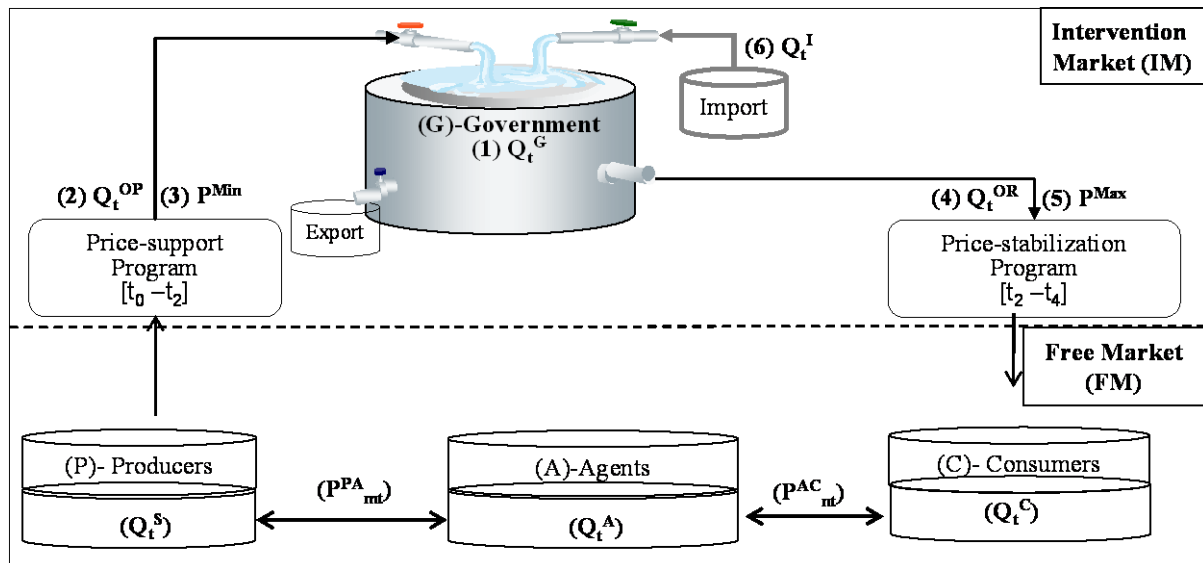


Figure 1. Framework of stocks and flows model at intervention market

Figure1. presents the comparison of transaction between free-market and interventioned-market. In free-market, the theory of supply and demand states that price itself is determined by supply and demand forces. At the harvest season, producer sells staple-food to the agent, and the agent sells them to the consumer. The market-price (producer-agent and agent-consumer) sets off equilibrium process. At the planting season, agent sells staple-food to the consumer. The market-price (agent-consumer) sets off equilibrium process. Firms with excess inventories cut prices to try to undersell their competitor.

In interventioned-market, the market-price is determined by supply-demand forces and buffer stock schemes forces. At the harvest season, government intervenes the market with

the price-support program when the market-price falls. Price support program is conducted through the procurement program from domestic-market. Government purchases the staple-food in boom periods so that the market-price goes up. At the planting season, the government intervenes the market when the market-price soars with the price-stabilization program. The price-stabilization program is conducted through the market-operation from staple-food owned by government. The government releases the staple-food in bush periods so that the market-price goes down.

3. MODEL DEVELOPMENT

The notations of mathematical model is derived with the following (Table 1.):

Table 1. Notation of parameters and decision variables

Parameters:	
C_P	: Cost of production by Producer (thousand IDR/kg),
C_A	: Cost of distribution by Agent (thousand IDR/kg),
C_G	: Cost of market operation by Government (thousand IDR/kg),
P_t^{PA}	: The price producer-agent in t period in free market (thousand IDR/kg),
P_t^{AC}	: The price agent-producer in t period in free market (thousand IDR/kg),
P_t^{*PA}	: The price producer-agent in t period in intervention market (thousand IDR/kg),
P_t^{*AC}	: The price agent-producer in t period in intervention market (thousand IDR/kg),
P^I	: A purchase cost per unit of the staple-food from import (thousand IDR/kg),
IRR	: Internal Rate of Return as the minimum margin profit-indicator (%),
NRR	: Normal Rate of Return as the common margin profit-indicator (%),
SRR	: Speculative Rate of Return as the maximum margin profit-indicator (%),
Q_t^S	: Total supplies of staple-food from Producer in t period (tons),
Q_t^D	: Total demand of staple-food from Consumer in t period (tons),
Q_t^A	: Total demand of staple-food from Agent in t period (tons),
Q_0^G	: Amount of staple-food owned by government in the beginning period (tons),
h	: A holding cost per unit in stock per unit of time (thousand IDR/ton/year),
T	: Length of time periods, index for time period, $t = (1, 4)$.
Decision Variables:	
P^{Min}	: The minimum price-limit (thousand IDR/kg),
P^{Max}	: The maximum price-limit (thousand IDR/kg),
Q_t^{OP}	: Amount of staple-food should be purchased from market in t period (tons),
Q_t^{OR}	: Amount of buffer stock should be released to market in t period (tons),
Q_t^I	: Amount of import's supply in t period (tons),
Q_t^G	: Amount of staple-food owned by government in t period (tons).

First, let consider the simple one-staple-food market model, it is only governed by the amount of staple-food's demands in t period (Q_t^D) from the consumer, the amount of staple-food's production in t period (Q_t^S) from the producer, the amount of market's supplies in t period (Q_t^A) from the agent, and its price (P_t). Based on partial market equilibrium theory (a linear model), we translated the simple one-staple-food market model with the following:

$$Q_t^D = a + bP_t^C, \quad a, b > 0; \quad (1)$$

$$Q_t^S = -c + dP_t^P, \quad c, d > 0; \quad (2)$$

$$Q_t^A = -e + gP_t^A, \quad e, g > 0; \quad (3)$$

Where (a, c, e) are constants; (b, d, g) are point price elasticity; then (a, c, e) and (b, d, g) should be mutually independent parameters.

The objective of development proposed-model is to determine instruments of Market-intervention program for giving maximal benefit to the producer (P) and the consumer (C), and also for giving minimal loss/expenditure to the agent (A) and the government (G). Total benefit or total losses of market-intervention program can be calculated pursuant to total difference between total revenue and total cost at Free Market with Intervention Market for each stakeholder. The description of earnings or expenditure in each stakeholder is presented at Table 2.

Table 2. The description of earnings or expenditure in each stakeholder

Component	Free Market (FM)	Intervention Market (IM)
(P) Total revenue	The multiplication of total supply from the producer at the selling-price of producer-agent.	- The amount of staple-food bought by the government multiplied by the minimum price-limit. - The amount of staple-food sold to markets at the price of producer-agent.
Total production cost	The total production cost is obtained as the production cost per unit of item multiplied by the quantity of production.	
(C) Total consumption cost	The total demand of consumer multiplied by selling-price of agent-consumer.	- Period t1-t2: the total demand of consumer multiplied by selling-price of agent-consumer. - Period t3-t4: consumer bought the amount of staple-food at the maximum price-limit when market-operation controlled by the government, and the remain one bought at selling-price of agent-consumer.
(A) Total revenue	The multiplication of total supply to consumer at the selling-price of agent-consumer.	The total sales is calculated by total consumer's demand minus the amount of buffer stock when market-operation done. The revenue is obtained as the selling-price of agent-consumer multiplied by the Total sales.
Total procurement cost	The amount of staple-food bought from the producer at selling-price of producer-agent.	
Total distribution cost	The total distribution cost is obtained as the distribution cost per unit of item multiplied by total demand of staple-food from the consumer.	
Total inventory cost	The total inventory cost is obtained as a holding cost per unit in stock per unit of time multiplied by total of average inventory in a year.	
(G) Total procurement cost	-	- The amount of staple-food bought by the government from the producer at the minimum price-limit. - The amount of staple-food bought by the government from import at a purchase cost per unit of the staple-food from import.
Total distribution cost	-	The total distribution cost is obtained as cost of market operation by the government multiplied by amount of buffer stock should be released to market.
Total inventory cost	-	The total inventory cost is obtained as a holding cost per unit in stock per unit of time multiplied by total of average the government's inventory in a year.

Total revenue	-	The multiplication of amount of buffer stock should be released to market at the maximum price-limit.
Total intervention cost	-	The total intervention cost is obtained as total revenue minus the procurement cost, the distribution cost and the inventory cost.

We proposed buffer stocks schemes that consist of 6DVs as instruments for market-intervention program. According to the description either expenses or earning in each stakeholder shown in Table 2., we can formulate the objective function for each stakeholder. The objective function of proposed-model for the producer is to maximize difference total profit between IM and FM; and for the consumer is to maximize difference total expenditure between IM and FM. The objective function of proposed-model for the agent is to minimize difference total expenditure between IM and FM; and for the government is to minimize difference total expenditure between IM and FM. Translated into mathematical statements, the total benefit or total cost for producer, consumer, agent and government can be written as:

$$TB^P = \sum_{t=1}^2 (P_t^{\text{Min}Q_t^{\text{OP}}}) + P_t^{\text{PA}} (Q_t^S - Q_t^{\text{OP}}) - \sum_{t=1}^2 P_t^{\text{PA}} Q_t^S \quad (4)$$

$$TB^C = \sum_{t=1}^4 P_t^{\text{AC}} Q_t^D - \sum_{t=1}^2 (P_t^{\text{Min}Q_t^{\text{OP}}}) + P_t^{\text{PA}} (Q_t^S - Q_t^{\text{OP}}) - \sum_{t=1}^2 P_t^{\text{PA}} Q_t^S \quad (5)$$

$$TC^A = [\sum_{t=1}^4 P_t^{\text{AC}} Q_t^D - \sum_{t=1}^2 P_t^{\text{PA}} Q_t^S - \sum_{t=1}^4 C_A Q_t^D - \sum_{t=1}^4 \frac{h}{4} Q_t^A] \quad (6)$$

$$TC^G = \sum_{t=1}^2 P_t^{\text{min}Q_t^{\text{OP}}} + \sum_{t=3}^4 P_t^I Q_t^I + \sum_{t=3}^4 C_G Q_t^{\text{OR}} + \sum_{t=1}^4 \frac{h}{4} Q_t^G - \sum_{t=3}^4 P_t^{\text{max}Q_t^{\text{OR}}} \quad (7)$$

In this paper, a buffer stock model considers four expectation of stakeholders. The performance criterion of the model is to maximize the benefit of both the producer and the consumer and to minimize the total expenditure of the agent and the government. The formulation a multi-objectives programming model is as follows:

$$\text{Objective (1): } \text{Max. } TB^P + TB^C \quad (8)$$

$$\text{Objective (2): } \text{Min. } TC^A + TC^G$$

All constraints are classical like the market-price rules, the formulation of stakeholder's expectation, the requirement of buffer stock and market clearing of dynamic equilibrium. The model is subject to:

$$\bar{P}_t^{\text{PA}} = [(\frac{a+c}{b+d}) - \gamma(Q_{t-1}^A + Q_t^S - Q_t^D)] \quad (9)$$

$$\bar{P}_t^{\text{AC}} = (\frac{a+e}{b+g}) - \gamma Q_t^A \quad (10)$$

$$\bar{P}_t^{\text{PA}} = [(\frac{a+c}{b+d}) - \gamma(Q_{t-1}^A + Q_t^S - Q_t^D - Q_t^{\text{OP}})] \quad (11)$$

$$\bar{P}_t^{\text{AC}} = [(\frac{a+e}{b+g}) - \gamma(Q_t^A - Q_t^{\text{OP}})] \quad (12)$$

$$VT_1 \leq (P_t^{\text{PA}}, P_t^{\text{Min}}) \leq VT_2, t \in (1,2) \quad (13)$$

$$VT_1 = C_p (1 + IRR) \quad (14)$$

$$VT_2 = ((P_t^{PA} + C_A) \times (1 + IRN) - C_A) \quad (15)$$

$$VT_3 \leq (P_t^* AC, P^{Max}) \leq VT_4, t \in (3,4) \quad (16)$$

$$VT_3 = (P_t^{PA} + C_P)(1 + IRR) \quad (17)$$

$$VT_4 = (P_t^{PA} + C_A)(1 + IRS) \quad (18)$$

$$\sum_{t=1}^4 (Q_{t-1}^A + Q_t^S - Q_t^{OP} + Q_t^{OR}) \geq \sum_{t=3}^4 Q_t^D, t \in (1,4) \quad (19)$$

$$Q_{t-1}^G + Q_t^{OP} > 0, t \in (1,2) \quad (20)$$

$$Q_{t-1}^G - Q_t^{OR} + Q_t^I > 0, t \in (3,4) \quad (21)$$

$$Q_t^S + Q_t^A - Q_t^{OP} \geq Q_t^D, t \in (1,2) \quad (22)$$

$$Q_t^A + Q_t^{OR} \geq Q_t^D, t \in (3,4) \quad (23)$$

$$P^{Min}, P^{Max}, Q_t^{OP}, Q_t^{OR}, Q_t^I, Q_t^G \geq 0, t \forall T \quad (24)$$

Objective function (8) corresponds to function of multi-objectives in equation (4) until (7), aims to maximize the benefit of both producer and consumer, and to minimize the total losses or expenditure of agent and government. In free-market, we proposed a market model with inventory to determine the selling-price producer-agent and the selling-price agent-consumer, equations (9) and (10). In intervention-market, we modify a market model with inventory minus the amount of staple-food bought by the government, equations (11) and (12). Where γ denotes the stock-induced-price adjustment coefficient.

We introduce constraints (13), (14) and (15) to ensure that the price-equilibrium fulfilled the expectation of the producer and the agent at price-support program. The producer's expectation is protected from distortion of selling-price as impact of excess supply; and the agent's expectation is protected from buying-price that costly as the impact of price-floor regulated by the government. We have to ensure the expectation of the agent and the consumer at price-stabilization program in each period by considering the constraints (16), (17) and (18). The agent's expectation is protected from fall of selling-price as impact of ceiling-price regulated by the government; and the consumer's expectation is the availability of staple-food at rational selling-price for consumer. The government has to ensure the market-intervention program could fulfil the demand in each period, constraint (19). We have to ensure that the buffer stock schemes are adequate to hold the market-intervention program in each period by considering the constraints (20) and (21). Finally, we have to ensure the supply of staple-food are adequate the demand in each period and to ensure that all decision variables cannot be negative by considering the constraints (22), (23) and (24).

The optimal solution can be obtained by solving the pre-emptive of the multi-objectives programming above. We provide an algorithm to solve the problem illustrated above. The computation technique follows this algorithm:

- (i) calculate initial price for each supply-availability-demand function, equation (1) until (7),
- (ii) input model equation (8) until (24) to determine decision variables into GP-ILP software i.e. WinQSB, and
- (iii) calculate objective function by using WinQSB software and determine each stakeholders objectives.

4. NUMERICAL EXAMPLES AND ANALYSIS

In this section, we present numerical examples and analyse them to evaluate the total stakeholder's benefit. We consider a set of hypothetical-parameters reflecting one-staple-food market model. It is only governed by the amount of staple-food's demand, staple-food's production, market's supplies, and its price. The parameters used for the computational example is presented in Table 3. A computational result under a set of price elasticity of supply is given as numerical example.

Table 3. Parameters of supply-availability-demand (in Units)

Parameter	a	b	c	d	e	g	γ	h
Value	32.0	0.17	167.0	4.8	0.1	0.45	0.1	2.0
Parameter	C_A	C_G	C_P	P^I	IRR (%)	NRR (%)	SRR(%)	
Value	2.0	4.0	34.0	40.0	5.0	10.0	25.0	

First, we processed on determining the DVs by using Parameters in Table 3. We processed on determining the decision variables by using GP-ILP software. Computational results are shown in Table 4.

Table 4. A computational of decision variables

DVs	P^{Min}	P^{Max}	Q_t^{OP}		Q_t^{OR}		Q_t^I		Q_t^G			
Period	t ₁ -t ₂	t ₃ -t ₄	t ₁	t ₂	t ₃	t ₄	t ₃	t ₄	t ₁	t ₂	t ₃	t ₄
Value	35.7	45.6	0.0	21.6	21.6	21.6	21.6	21.6	0.0	21.6	21.6	21.6

The proposed-model has estimated improving the selling-price producer-agent and degrading the selling-price agent-consumer. The mechanism of improving/degrading is explained by a market model with inventory. A comparative analysis of price-equilibrium between FM and IM is depicted in Table 5.

Table 5. A comparative analysis of price-equilibrium between FM and IM

	t_0	t_1	t_2	t_3	t_4
P_t^{PA}	40.04	36.54	33.54		
P_t^{*PA}	40.04	36.54	35.70		
P_t^{AC}	51.77	48.27	45.27	47.77	50.27
P_t^{*AC}	51.77	48.27	47.43	45.61	48.11

Based on Table 5, we provide rise or fall of price between free market and intervention market. The government conducts the price support program through the procurement program from domestic-market at period t_2 , so that the market-price goes up. At the planting season $[t_3-t_4]$, the government conducts market-operation through release buffer-stock, so that the market-price goes down.

Table 6. A comparative analysis between FM and IM

Stakeholder	Expectation	Notation	FM (Mil. IDR)	IM (Mil. IDR)	Loss/Benefit (Mil. IDR)
(P)	Total Revenue	(TR^P)	3,123.62	3,242.42	
	Production Cost	(TC^P)	3,060.00	3,060.00	
	Profit		63.62	182.42	118.79
(C)	Consumption Cost	(TC^C)	4,789.92	4,681.74	108.18
(A)	Total Revenue	(TR^A)	4,789.92	2,711.39	
	Procurement Cost	(TC_P^A)	3,123.62	2,471.30	
	Distribution Cost	(TC_D^A)	200.00	113.60	
	Inventory Cost	(TC_I^A)	77.50	79.20	
	Profit		1,388.80	47.29	1,341.51
(G)	Procurement Cost	(TC_P^G)		2,499.12	
	Distribution Cost	(TC_D^G)		172.80	
	Inventory Cost	(TC_I^G)		32.40	
	Total Revenue	(TR^G)		1,970.35	
	Intervention Cost	(TC^G)			733.97

*) Total Intervention Cost / Total Consumption Cost

Based on Table 6., the market-intervention program has significantly effect to reduce risks of both the producer and the consumer. We process on determining the stakeholder's expectation based on Table 4 and Table 5 for Free-Market and Intervention-Market. The loss/benefit is obtained as calculation of the difference between total revenue and total cost at Free-Market and intervened-market for each Stakeholder. For a set of hypothetic-parameters given, it can be noted that each of total benefit for the producer and the consumer in loss/benefit ratio are 186.72% and 2.26%, respectively. Total cost for the government and the agent in loss/benefit ratio are 15.32% and 96.59%, respectively. For price elasticity given, the producer obtains the benefit bigger than consumer. Furthermore, the agent obtains the cost/loss bigger than the government.

5. CONCLUSION

This paper provides a buffer stock model for stabilizing price with considering the stakeholders' expectation in the staple-food distribution system. The proposed-model has a significant effect to enhance the benefit for both the producer and the consumer under the minimum cost/losses for agent and government. The proposed-model is developed based on the integration of optimization model (multi-objectives programming) and econometrics model (a price-equilibrium model with inventory). A proposed-model is able to obtain the buffer stock program that its decision variables consist of the quantity, time, and price. The revenue of price stabilization is intended to induce an equivalent reduction in the fluctuations of total market revenue. Moreover, the producer gets bigger benefit than the consumer does, and the agent gets bigger cost/losses than the government does.

This paper has a certain limitation that should be overcome in order to provide a deep analysis on the function of a dynamic buffer stock. The ongoing research is dedicated to include more realistic price stabilization policy using parameters that appropriate to Indonesian sugar market. Then, further research will focus on other characteristics of intervention problems, including the effects of multi-player of producer, consumer and agent.

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